

**Development of Graphical User Interface (GUI) for the Synthesis of  
Microwave Amplifier**

by

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14949

Dissertation submitted in partial fulfilment of

the requirements for the

Bachelor of Engineering (Hons)

(Electrical & Electronics)

JANUARY 2015

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CERTIFICATION OF APPROVAL

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(ELECTRICAL & ELECTRONICS)

Approved by,

---

(Dr Wong Peng Wen)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

JANUARY 2015

## CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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FELICIA CHIEW PEI WAN

## ABSTRACT

The project was designed to develop a Graphical User Interface (GUI) for the synthesis of a microwave amplifier. GUI is a graphical tool which involves the interaction between an electronic device and user. The synthesis of the microwave amplifier using classical method such as Smith Chart is time-consuming as well as promotes low accuracy and inefficient. Besides, the tedious calculation of the polynomial equation involves during the designing process will slower down the synthesis process. Therefore, GUI is an important tool to speed up the synthesis of the microwave amplifier. The scopes of study of the project are divided into three main phase which are theoretical modelling, implementation of synthesis algorithm of the microwave amplifier and GUI development. The methodology involved for the synthesis of microwave amplifier using GUI starts with the desired specification by the user followed by the selection of the correct model of the transistor, identification of the S-parameters from the touchstone file, checking the input and output return loss, stability factor, noise figure and gain, identification of the source and load impedance and lastly is the lumped-element impedance matching network. For example, center frequency of 16.5GHz is generated when taking the average of frequency 1 (16 GHz) and 2 (17 Hz). The user specification will be drain voltage (1.5 V), drain current (10 mA), input band gain (12 dB), input return loss (5 dB), output return loss (10 dB), noise figure (3 dB) and characteristic impedance of 50Ω. Transistor model of ATF 36077 is chosen and the S-parameters of the particular transistor at 16.5 GHz are  $-0.30+j0.47$  ( $S_{11}$ ),  $2.37+j2.25$  ( $S_{21}$ ),  $0.05-j0.07$  ( $S_{12}$ ) and  $-0.29+j0.048$  ( $S_{22}$ ). The stability factor is 1. Maximum unilateral transducer gain (MUTG) is 12dB and it is being compared with the input band gain (11 dB). It is acceptable since the acceptable range of MUTG is +/- 1dB of the input band gain. On the other hand, the source impedance is  $27-j2.9$  while the load impedance is  $18-j25$ . The noise figure when the center frequency is at 16.5 GHz will be 0.63 dB. It is acceptable since the lower the noise figure, the better the amplifier design. For the input matching network, the capacitance is 0.000258 F while the inductance is 0.469 H. The capacitance and inductance for the output matching network will be 0.000199 F and 0.361 H respectively. The project can be contributed to microwave amplifier designer and software developer to speed up the performance on the synthesis of microwave amplifier.

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## **LIST OF ABBREVIATION**

|              |   |
|--------------|---|
| BJT          | Bipolar Junction Transistor                     |
| CAD          | Computer-Aided Design                           |
| FET          | Field Effect Transistor                         |
| FYP          | Final Year Project                              |
| GaAs FET     | Gallium Arsenide Field Effect Transistor        |
| GUI          | Graphical User Interface                        |
| IEEE         | Institute of Electrical & Electronics Engineers |
| MATLAB       | Mathematics Laboratory                          |
| RHP          | Right Hand Plane                                |
| S-Parameters | Scattering Parameters                           |



# **CHAPTER 1**

## **INTRODUCTION**

### **1.1 Background of Study**

Amplifier is a crucial part in instruments in our daily life. It is an electronic device that increases the voltage, current, or power of a signal [1]. An amplifier operates by matching the input signal shape with higher amplitude by adjusting the output and the energy source of the amplifier is drawing directly from power supply. The input signal always weaker than the output signal of the power supply because amplifier works to amplify the output of the power supply. There are many types of amplifier that has been used in market today such as microwave amplifier, distributed amplifier, operational amplifier, transistor amplifier, power amplifier and etc.

In this paper, the author will be emphasized on the designing of microwave transistor amplifier. When the microwave transistor amplifier is applied, the output power signal of a microwave transistor amplifier will be increased which directly increases the amplitude of the waveform of the output signal. The increasing amplitude of the waveform of the output signal will contribute to higher power level of the microwave devices. It can be done when more input power are channeled to the microwave devices that lead to the increasing energy carried by the microwave radiation. [2]

In microwave system, microwave transistor amplifier involve the combination between the passive transmission line circuits and active elements. Bipolar Junction Transistor (BJT's) and Gallium Arsenide Field-Effect Transistor (GaAs FET's) is the transistor technology in which their amplifier design techniques are based on the study of the transmission lines theory, network analysis and the Smith Chart presentation. [3] The design of the microwave transistor amplifier often involves the

transistor selection, parameters identification, stability computation and matching network design.

The design of the microwave amplifier starts with the transistor selection. Transistor selection is crucial and it is dependent on the design specification for a particular microwave amplifiers. The transistors that are usually employed in the microwave circuits are BJT's and GaAS FET's respectively. Depending on the design specification, BJT's are used if the frequency is below 4GHz and GaAS FET's is utilized if the frequency above 4GHz is required. The transistor selection becomes more tedious when the stability of the transistor is take into consideration. The process of designing microwave amplifier continues with the parameters identification. The transistor equivalent circuit models based on device physics during the amplifier designing can provide the information on the S-parameters of the microwave transistor through some mathematically derivation. S-parameters data will be provided by the manufacturer of the specific device which intended to be used for microwave application to improve the accuracy of the microwave transistor amplifier design. For each of the S parameters, the magnitude and phase angle will vary with frequency.

In addition, stability is also a point of interest that must be taken care during microwave transistor amplifier designing. For the stability check using Smith Chart, the design value of the input or output reflection coefficient must be located outside the stability circle to prevent the oscillation of the designed amplifier. Proper calculations and plotting of the values in the stability circle are required to ensure that the microwave amplifier designed is stabilize. The matching of the network is aimed to eliminate the reflections at terminal for wave incident from the source. Matching network may consist of lumped elements or of sections of transmission lines with appropriate lengths and terminations. The matching network often involves complicated calculation which may slow down the process of designing microwave amplifier.

The designing of microwave amplifier which involves numerical and graphical methods such as Smith Chart are time-consuming and tedious. Besides, much effort are needed for the selection of the parameters and complicated mathematical calculations. The process of microwave amplifier can be speeding up through the

implementation of synthesis algorithm through a Graphical User Interface (GUI). GUI development helps to speed up the designing effort as it serves as a template for the entry of the design parameters. All of the calculations and analysis will no longer needed to be done manually after the development of GUI using MATLAB software.

## **1.2 Problem Statement**

Designing of microwave transistor amplifier utilizes different techniques ranging from Smith Chart to graphical cut-and-try approach. Both of the approaches used previously has no significance effect on speeding up the design effort of the microwave transistor amplifier. A typical microwave transistor amplifier design requires a lot of effort and time which involves the transistor selection, parameters identification, stability computation and matching network design. Classical design technique which requires the user to manually choose the transistor and perform the synthesis of the matching network will consume much time. The process will be delayed when the designing process involve complex polynomials and complicated calculations. Apart from that, the quality of the microwave amplifier design will be affected if there is error during the calculation of the complex polynomial. It will definitely cause the accuracy of the designed microwave amplifier to decrease. Realizing the problem arise if the designing of microwave transistor amplifier is to be done using classical method, this Final Year Project (FYP) work aims to provide an alternative solution to speed up the design effort by the implementation of synthesis algorithm through a GUI. GUI enables the user to input the design parameters and the calculations are done using the computer synthesis tool which promotes time saving in designing the microwave transistor amplifier. Hence, the accuracy and quality of the microwave transistor amplifier can be uphold if the designing process of microwave transistor amplifier can be done using the development of GUI.

### **1.3 Significance of Project**

The research is very significant as the implementation of synthesis algorithm through a GUI will bring improvement on synthesis of microwave transistor amplifier design. It helps to boost up the process of the design of microwave transistor amplifier as well as increase the accuracy of the designed project. As the research is focusing on the synthesis of microwave amplifier through the development of GUI, the author will be familiarized with the theoretical modelling of microwave amplifier and at the same time improves the programming skills that use to develop GUI at the end of the project.

## **1.4 Objectives**

The objectives of the research aimed to:

- To study the theoretical modelling and perform the implementation of synthesis algorithm.
- To develop a GUI for the synthesis of microwave amplifier using MATLAB software.

## **1.5 Scope of Study & Project Feasibility**

The overall research is to provide an alternative solution to increase the speed of the design works by implementing the synthesis algorithm through development of GUI. It has been identified that the classical methods for the synthesis of microwave transistor amplifier involves tedious analysis and time-consuming calculations which may slow down the process in order to design a microwave amplifier. GUI development is a user-friendly computer aided tool which only prompt the user to input the required design parameters. Hence, this automated software makes the designing task to be done in a simpler and faster way. At the same time, the quality and accuracy of the designing task is guaranteed compared when using classical methods. The scope of the study for the research involves are:

- i. Theoretical modelling of microwave amplifier
- ii. Implementation of synthesis algorithm
- iii. GUI development using MATLAB

The scope of the study is feasible within the time frame given. The author were given a duration of two semesters (FYP 1 and FYP 2) to accomplish and achieve the final goal of the research works. FYP 1 is focusing more on the early research study and theoretical modelling of microwave amplifier while the GUI development will be implemented in FYP 2 after the implementation of synthesis algorithm is done. Besides, the research is feasible in term of knowledge as the scope of study is within the capabilities of the author. Several research journals, online forums, online tutorials and books provide detailed information of the designing of microwave amplifier as well as the GUI development.

### **1.6 Relevancy of Project**

The research project is relevant because it provide an alternative solution to speed up the synthesis of microwave transistor amplifier. Classical techniques used often involve tedious work and calculation of complicated polynomial equation which may lead to error sometime. Hence, by developing the GUI the synthesis process of the microwave transistor amplifier can be tremendously improved in term of time and accuracy.

## CHAPTER 2

### LITERATURE REVIEW

Nowadays, in order for the microwave circuit market to be excellence and competitive with other market, performance requirements of the microwave amplifier must be highly achievable. In the process of designing a good microwave amplifier, having a flat frequency response in the matching network is crucial especially in the current industries practice. On the other hand, certain specification of the circuit must be met although some of the variation in the parameters of the circuit are unavoidable. Despite the parameter variation, a designer must consider the stability factor of a circuit in their robust design. Therefore, from the previous studies, to ascertain the stability of the design, stability factor, Rollet Factor K [4] is used by the microwave designer. However, this approach is proven failed by several authors [4-8] because it is only valid if there is no RHP pole of the S-parameters two port network. On top of that, circuit optimization is performed before the stability check. Hence, the method is said to be ineffective as it consumes much time during the trial and error design methodology. The problem is solved when a new design methodology is presented in which the synthesis process of circuit can be done using the Computer Aided-Synthesis (CAD) tools including stability among optimizer goals. [7] On the other hand, several previously published unconditional stability criteria of a 2-port networks are being discussed as below but it is found that the Rollet Factor, K which satisfy  $K > 1$  and  $|\Delta| < 1$  is simpler.

$$\rho_{11} = \frac{S_{11} - \Delta \rho_L}{1 - S_{22} \rho_L} \quad (2.1)$$

$$\Delta = S_{11}S_{22} - S_{12}S_{21} \quad (2.2)$$

$$K = \frac{1 - |S_{11}|^2 - |S_{22}|^2 + |\Delta|^2}{2|S_{12}S_{21}|} \quad (2.3)$$

**Case I: Three conditions to be satisfied simultaneously**

$$K > 1 \quad (2.4)$$

$$|S_{11}| < 1 \quad (2.5)$$

$$|S_{22}| < 1 \quad (2.6)$$

**Comments:** The three conditions are insufficient for unconditional stability. The condition of  $K > 1$  is satisfied but if the load is short circuited, the network becomes unstable.

**Case II: Four conditions to be satisfied simultaneously**

$$|S_{11}| < 1 \quad (2.7)$$

$$|S_{22}| < 1 \quad (2.8)$$

$$\left| \frac{|S_{12}S_{21}| - |S_{11} - \Delta S_{22}^*|}{|S_{11}|^2 - |\Delta|^2} \right| > 1 \quad (2.9)$$

$$\left| \frac{|S_{12}S_{21}| - |S_{22} - \Delta S_{11}^*|}{|S_{22}|^2 - |\Delta|^2} \right| > 1 \quad (2.10)$$

**Comments:** The four conditions are mathematically correct but complicated.

**Case III: Two conditions to be satisfied simultaneously**

$$1 - |S_{11}|^2 - |S_{22}|^2 - 2|S_{12}S_{21}| + |\Delta|^2 > 0 \quad (2.11)$$

and either

$$1 - |S_{11}|^2 - |S_{12}S_{21}| > 0 \quad (2.12)$$

or

$$1 - |S_{22}|^2 - |S_{12}S_{21}| > 0 \quad (2.13)$$

**Comments:** Mathematically correct but unnecessarily complicated.

The classical technique used to design the microwave amplifier is presented in [8]. This approach involves tedious work and increasing the human errors when designing the microwave amplifier. Figure 1 shows the microwave transistor amplifier general circuit. The design of microwave amplifier is a step by step procedures and can be used with two different types of transistor that are bipolar and field effect transistor (FET). The S-parameter of the transistor design approach is used. It will start with the stability analysis in bilateral case. Besides, calculation for defining safe input and output area is performed via the stability circle for input and output. After that, the design of the input and output matching gain contribution via unilateral gain circle



said to simplify the analysis. The microwave simulator is then used to optimize the design matching circuits for getting the amplifier layout.

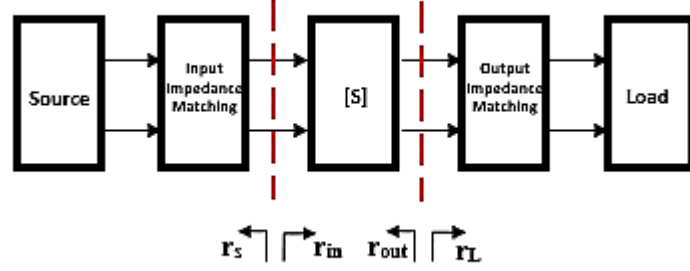


FIGURE 1. Microwave Transistor Amplifier General Circuit

Most of the matching network has been synthesized using the classical approaches. In arriving with the situation above, as opposed from the classical technique described in [8], the approach of HP9830 calculator-based synthesis routine speed up the synthesis process of inter-stage network and provide an accurate design of microwave amplifier. [9] In addition, synthesizing network of prescribed gain as well as the impedance transformation and parasitic element inclusion is able to be done through the calculator-based synthesis routine. All of the calculations in the synthesis process will be calculated using the calculator-based synthesis routine while leading to time saving during the whole synthesis process. NETSYN program is used for synthesizing inter-stage purpose. In this technique, transmission line equivalents is transformed from the network inter-stage and then the design predictions is compared with the measured performance of the amplifier.

Time-consuming traditional approach leads to the matching network of the inter-stage synthesis being slower down. To alleviate the problem in [8], a commercially available mathematical package to speed up the design effort is presented in [10]. It has an additional feature to compensate for the transistor roll-off and giving the amplifier with a flat response. With the advancement of technology, a GUI is going to be implemented in the research work which allows the synthesis o

the inter-stage matching network with variable slopes to compensate for the gain roll-off. The GUI that is going to be implemented in the research work is done using MATLAB. It serves as a user-friendly platform for the whole designing process. Users are prompt to enter the specific design parameters and the synthesis process will be automated. It may reduce the human errors and at the same time shorten the time needed for designing of microwave amplifier. Moreover, through the development of GUI, it opens up the opportunity to develop a useful design tools and at the same time capitalizing on the ease of use of the interface offered by MATLAB software.

The literature reviews is obtained from a reliable source which is mostly taken from the Institute of Electrical & Electronics Engineers (IEEE) Xplore. It is a database that store the citations and the research work done by the previous researches in different aspects of studies. The advancement of the technology leads to the research done in the recent year has higher accuracy and quality in terms of research works.

## CHAPTER 3

### METHODOLOGY/PROJECT WORK

#### 3.1 Research Methodology

The research methodology serves as an early planning or guide on how the overall research can be carried out throughout the two semesters. With the proper planning, the goal of the research that is to develop a GUI for the synthesis of microwave amplifier can be done in a time-consuming way and indirectly improve the time effectiveness of the research works. The general flow of the research methodology is shown in the flow chart below:

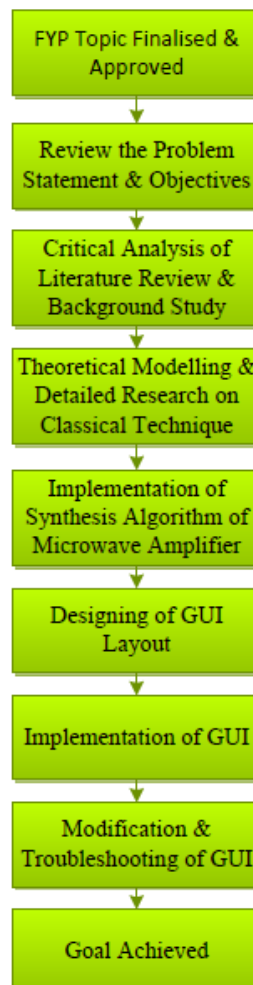


FIGURE 2. General Research Methodology

### 3.2 GUI Computation Flow

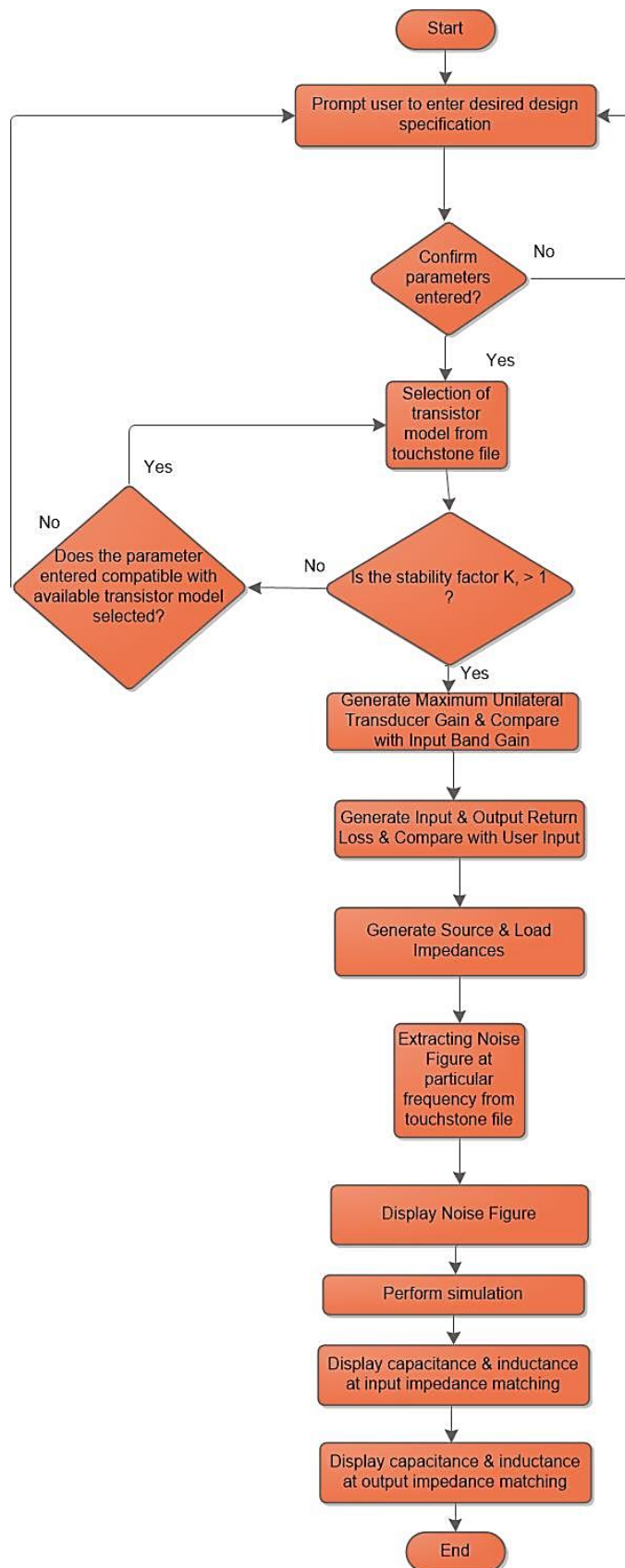
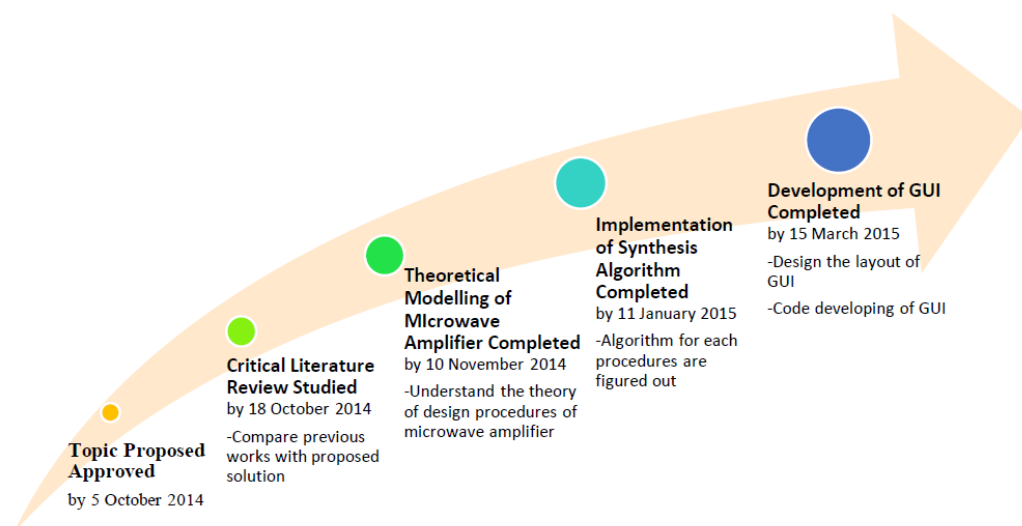


FIGURE 3. Flow Chart of GUI Computation Flow

### 3.2 Project Activities

The research is divided into four phases across the two semesters which is from September 2014 to April 2015. In order to organize the research work, one phase will only be carrying out after previous phase is completed to ensure the smooth flow of the project work. The four phases that will be carrying out across the two semesters will be early research study, theoretical modelling, and implementation of synthesis algorithm and development of GUI. In other words, FYP 1 is mainly focusing on the early research study, theoretical modelling of microwave amplifier. In FYP 1, the early research study is mainly focus on reading and doing literature review on the classical methods to design microwave amplifier. Several traditional techniques used in designing microwave amplifier is reviewed and learnt. The pros and cons of the traditional techniques used are carefully studied and compared. The theoretically modelling is a crucial phase as it provide theories and explain the procedures of typical microwave amplifier design. However, the implementation of synthesis algorithm will span across FYP 1 and FYP 2. The last phase which is the goal of this research work will be carrying out during FYP 2 that is development of GUI.

### 3.3 Key Milestones



### 3.4 Gantt Chart

TABLE 1. Gantt Chart



## CHAPTER 4

### RESULTS & DISCUSSION

#### 4.1 Theoretical Modelling of Microwave Transistor Amplifier

##### i. Two-Port Network Theory



FIGURE 4. Two-Port Network

A two-port network is referred as the electrical network in which the external circuits are being connected with two pairs of terminals. A port consist of two terminals and said to satisfy the port condition if for example the electrical current emerging from another terminal on the same port is the same as the current entering the current terminal. In this case, Port 1 and Port 2 are the input and output port respectively. Several parameters sets can be used in order to characterize the performance of the network. There are four variables are associated with the two-port model. Two of the variables (dependent variables) represents the response of the network to the excitation whereas the remaining two variables (independent variables) are representing the excitation of the network.

$V_1$  : voltage across port 1

$I_1$  : current into port 1

$V_2$  : voltage across port 2

$I_2$  : current into port 2

$$V_1 = AV_2 - BI_2 \quad (4.1)$$

$$I_1 = CV_2 - DI_2 \quad (4.2)$$

## ii. S-Parameters Technique

In order to develop GUI, S-parameters technique is employed in the project. S-parameters has the following advantages:

- Work at high frequency and easier to measure
- Can be used to measure on a device that is located at a distance from the measurement transducers, as long as the measuring device and the transducer are connected by low-loss transmission line.

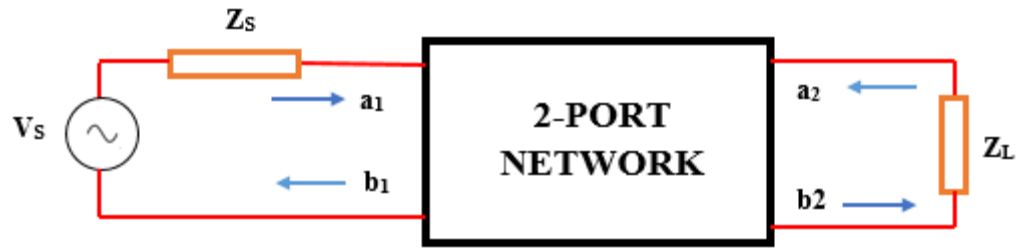


FIGURE 5. S-Parameters

The S-parameters are as below:

$$S_{11} = \left. \frac{b_1}{a_1} \right|_{a_2=0} \quad \text{Input reflection coefficient with the output port terminated by a matched load.} \quad (4.3)$$

$$S_{21} = \left. \frac{b_2}{a_1} \right|_{a_2=0} \quad \text{Forward transmission gain with the output port terminated in a matched load.} \quad (4.4)$$

$$S_{12} = \left. \frac{b_1}{a_2} \right|_{a_1=0} \quad \text{Reverse transmission gain with the input port terminated in a matched load.} \quad (4.5)$$

$$S_{22} = \left. \frac{b_2}{a_2} \right|_{a_1=0} \quad \text{Output reflection coefficient with the input port terminated by a matched load.} \quad (4.6)$$



### iii. Impedance Matching Network of Microwave Transistor Amplifier

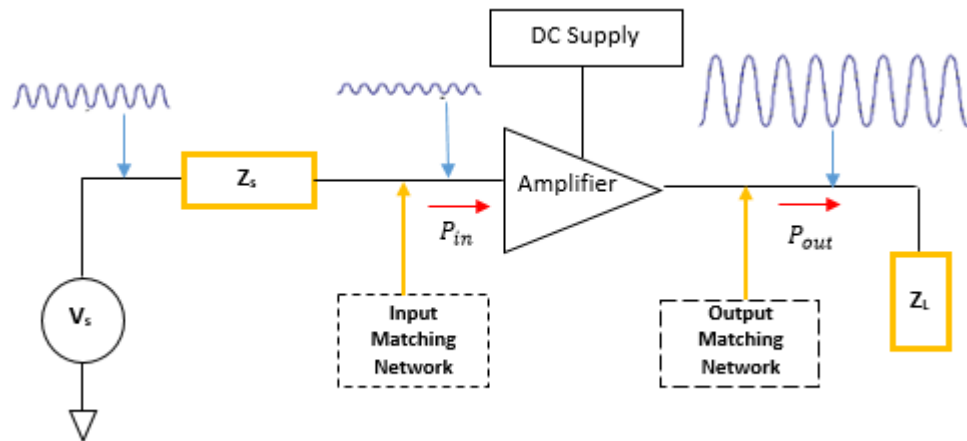


FIGURE 6. Block Diagram of Microwave Amplifier

A microwave transistor amplifier is a type of amplifier in which the increasing amplitude of the waveform of output signal will contribute to higher power level of microwave devices. The designing of microwave transistor amplifier often involve several steps starts from determining the suitable parameters to the impedance matching network.

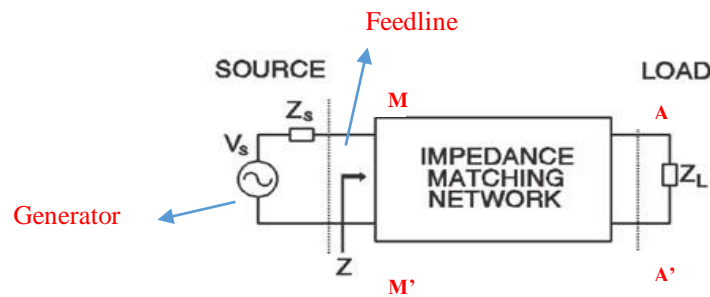


FIGURE 7. Impedance Matching Network

A matching network consists of extra circuit elements added in order to cancel out or compensate the variation of undesired performance and characteristics at specific frequency. An impedance matching network is to eliminate reflections at terminals  $MM'$  for waves incident from the source. Even though multiple reflections may occur between  $AA'$  and  $MM'$ , only a forward traveling wave exists on the feedline. Within the matching network, reflections can occur at both terminals ( $AA'$  and  $MM'$ ) and thus creating a standing-wave pattern but the wave incident from the source experiences no

reflection when it reaches terminal MM'. It can be achieved by designing the matching network to exhibit an impedance equal to  $Z_0$  at MM' when looking into the network from the transmission line side. All of the power going into it will end up in the load if the network is lossless. From Figure 5, the function of the impedance matching network is to transform the load impedance  $Z_L$  such that the input impedance  $Z$  looking into the network is equal to  $Z_0$  of the transmission line. It is important to have good design of impedance matching network for a microwave transistor amplifier. The good design of impedance matching network ensures that maximum power is being delivered to the load. In addition, when the signal power being transferred to the load is maximum with proper matched transmission line, the device sensitivity will increase.

#### **iv. Step-by-Step Procedures in Designing the GUI**

After understanding the basic theory of the microwave amplifier and the impedance input matching, to design a Graphical User Interface (GUI), there are certain parameters that we need to consider during the designing process. Below shows the step by step designing and factor to be considered to design a GUI for the synthesis of microwave amplifier.

##### **Step 1:**

In order to design the microwave amplifier, first we need to prompt the user to key in certain parameters. The parameters that are needed to key in by the user are:

- Frequency Band (within a range between  $f_1$  and  $f_2$ )
- Input and Output Impedance Level,  $Z_0$
- Drain Bias,  $V_{DS}$  &  $I_{DS}$
- Input Band Gain
- Input Return Loss
- Output Return Loss
- Noise Figure

After the user key in the input, a message dialogue box will be appeared on the screen. User is given a choice to choose for confirm the parameters that they entered before proceeding. If the user wants to make changes to the parameters, option No will be clicked and it will return to the screen and now the user can start to make changes. At

the same time, if the user leaves the column to be emptied or input a non-numerical text, a warning text box will appear to ask for correction for the input parameters.

### **Step 2:**

#### **Finding the S-Parameters.**

Based on the Drain Bias,  $V_{DS}$  &  $I_{DS}$  and the center frequency,  $f_c$ , user is prompt to browse for the touchstone file of the transistor that contains the value of the S-Parameters that meets the user specification. The center frequency can be calculated using the formula below:

$$f_c = \frac{f_1 + f_2}{2} \quad (4.7)$$

After user input the frequency 1 and frequency 2, the system will automatically search and scan the  $f_c$  and obtain the values of the S-parameters of that specific center frequency from the touchstone file. The FIGURE 6 below shows the example of the S-Parameters.

#### **S-PARAMETER**

MAG. AND ANG.

$V_{DS} = 3 \text{ V}$ ,  $I_D = 10 \text{ mA}$

| FREQUENCY<br>MHz | S11   |        | S21   |       | S12   |       | S22   |        |
|------------------|-------|--------|-------|-------|-------|-------|-------|--------|
|                  | MAG.  | ANG.   | MAG.  | ANG.  | MAG.  | ANG.  | MAG.  | ANG.   |
| 500.0000         | 0.993 | -14.4  | 3.919 | 166.5 | 0.022 | 80.3  | 0.716 | -9.9   |
| 1000.0000        | 0.971 | -28.4  | 3.820 | 153.5 | 0.042 | 71.6  | 0.702 | -19.1  |
| 1500.0000        | 0.936 | -41.9  | 3.714 | 140.9 | 0.061 | 62.0  | 0.682 | -28.2  |
| 2000.0000        | 0.896 | -54.8  | 3.562 | 129.0 | 0.079 | 54.1  | 0.652 | -36.8  |
| 2500.0000        | 0.850 | -67.4  | 3.388 | 117.8 | 0.092 | 46.4  | 0.623 | -44.8  |
| 3000.0000        | 0.808 | -79.4  | 3.238 | 107.0 | 0.103 | 39.9  | 0.592 | -52.6  |
| 3500.0000        | 0.761 | -91.3  | 3.069 | 96.4  | 0.112 | 33.5  | 0.563 | -60.9  |
| 4000.0000        | 0.720 | -102.7 | 2.909 | 86.4  | 0.120 | 27.5  | 0.533 | -68.1  |
| 4500.0000        | 0.681 | -113.9 | 2.765 | 77.0  | 0.125 | 22.2  | 0.501 | -75.7  |
| 5000.0000        | 0.647 | -124.4 | 2.623 | 67.9  | 0.127 | 17.6  | 0.475 | -83.5  |
| 5500.0000        | 0.615 | -134.9 | 2.485 | 59.1  | 0.131 | 13.6  | 0.454 | -91.4  |
| 6000.0000        | 0.588 | -144.8 | 2.365 | 50.7  | 0.131 | 9.6   | 0.437 | -98.9  |
| 6500.0000        | 0.566 | -154.5 | 2.252 | 42.6  | 0.133 | 6.5   | 0.425 | -107.1 |
| 7000.0000        | 0.547 | -163.6 | 2.151 | 34.7  | 0.135 | 3.7   | 0.418 | -114.4 |
| 7500.0000        | 0.531 | -172.4 | 2.064 | 27.3  | 0.136 | 1.9   | 0.414 | -121.8 |
| 8000.0000        | 0.517 | 178.7  | 1.985 | 19.6  | 0.139 | -0.8  | 0.415 | -129.3 |
| 8500.0000        | 0.503 | 169.6  | 1.909 | 12.2  | 0.141 | -3.0  | 0.418 | -136.4 |
| 9000.0000        | 0.492 | 160.5  | 1.843 | 5.0   | 0.143 | -5.3  | 0.418 | -143.7 |
| 9500.0000        | 0.482 | 151.1  | 1.783 | -2.5  | 0.148 | -7.3  | 0.417 | -151.0 |
| 10000.0000       | 0.475 | 141.3  | 1.726 | -9.6  | 0.152 | -9.4  | 0.419 | -158.4 |
| 10500.0000       | 0.475 | 131.5  | 1.668 | -17.0 | 0.156 | -11.3 | 0.418 | -166.4 |
| 11000.0000       | 0.477 | 121.6  | 1.613 | -23.8 | 0.160 | -13.8 | 0.421 | -174.2 |
| 11500.0000       | 0.481 | 112.1  | 1.554 | -31.0 | 0.165 | -16.2 | 0.431 | 177.3  |
| 12000.0000       | 0.489 | 102.7  | 1.503 | -38.0 | 0.170 | -18.8 | 0.441 | 169.6  |

FIGURE 8. S-Parameters of the Transistor

For example, if the  $f_c = 500\text{MHz}$ ,

The S-Parameters that will be extracted will be:

$S_{11}$ :  $0.993\angle-14.4$

$S_{21}$ :  $3.919\angle166.5$

$S_{12}$ :  $0.022\angle80.3$

$S_{22}$ :  $0.716\angle-9.9$

However, the S-parameters extracted from the touchstone file will be displayed in rectangular form. Therefore, effort must be done to convert the S-parameters values back to the polar form (magnitude and phase angle). If the center frequency is not found in the list of the frequency in the touchstone file, interpolation is needed to perform in order to find the values of the S-parameters.

### **Step 3**

#### **Determine the stability factor of the microwave amplifier.**

In this step, it is crucial to choose a correct transistor to reduce the oscillation that will lead to the instability of the system. Negative resistance, in other words, magnitude of reflection coefficient greater than 1 will cause oscillation.

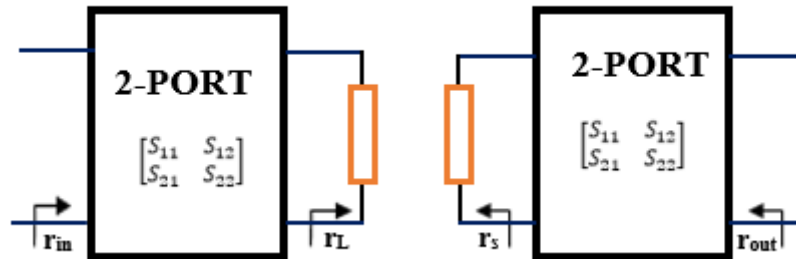


FIGURE 9. Two Ports Network of a Circuit Design

#### ❖ **Unconditionally stable**

$\Gamma_{in}$  and  $\Gamma_{out}$  both  $<1$  for all  $\Gamma_L$  and  $\Gamma_s$  such that  $\Gamma_s <1$  and  $\Gamma_L <1$ . No passive terminations give rise to negative resistance.

#### ❖ **Conditional stable/ Potentially unstable**

$\Gamma_{in} <1$  and  $\Gamma_{out} <1$  only for a certain range of passive source  $\Gamma_s$  and load impedance  $\Gamma_L$

In this case, we need to find the value of the Rollet's Stability Factor, K using the formula below. If  $K < 1$ , the user will be direct to the Step 1 to check whether the requirements entered are compatible with the model of the transistor selected and make changes to the requirements entered if necessary. The value of the S-parameters will be obtained from Step 2.

$$K = \left[ \frac{1 - |S_{11}|^2 - |S_{22}|^2 + |\Delta|^2}{2|S_{12}S_{21}|} \right] > 1 \quad (4.8)$$

$$1 - |S_{11}|^2 > |S_{12}S_{21}| \quad (4.9)$$

$$1 - |S_{22}|^2 > |S_{12}S_{21}| \quad (4.10)$$

$$\text{Where } \Delta = S_{11}S_{22} - S_{12}S_{21} \quad (4.11)$$

#### **Reflection Coefficient of the Load**

$$\Gamma_L = \frac{Z_L - Z_o}{Z_L + Z_o} \quad (4.12)$$

#### **Reflection Coefficient of the Source**

$$\Gamma_S = \frac{Z_S - Z_o}{Z_S + Z_o} \quad (4.13)$$

#### **Input Reflection Coefficient**

$$\Gamma_{in} = S_{11} + \frac{S_{12}S_{21}\Gamma_L}{1 - S_{22}\Gamma_L} \quad (4.14)$$

#### **Output Reflection Coefficient**

$$\Gamma_{out} = S_{22} + \frac{S_{12}S_{21}\Gamma_S}{1 - S_{11}\Gamma_S} \quad (4.15)$$

#### **Maximum Power Transfer occurs when:**

$$\Gamma_S = \Gamma_{in}^* \text{ and } \Gamma_S = S_{11}^* \quad (4.16)$$

$$\Gamma_L = \Gamma_{out}^* \text{ and } \Gamma_L = S_{22}^* \quad (4.17)$$

Therefore,

$$\Gamma_{in} = S_{11} \quad (4.18)$$

$$\Gamma_{out} = S_{22} \quad (4.19)$$

Whereby

$\Gamma_S$ : to the input matching network (from transistor to input)

$\Gamma_L$ : to the output matching network (from output transistor to output)

#### **Step 4**

**Determine and check the gain of the microwave amplifier.**

The effective Gain Factors,  $G$  maximized when:

$$\Gamma_s = S_{11}^* \quad (4.20)$$

$$\Gamma_L = S_{22}^* \quad (4.21)$$

$$G_{s,max} = 10 \log_{10} \left[ \frac{1}{1 - |S_{11}|^2} \right] \quad (4.22)$$

$$G_{L,max} = 10 \log_{10} \left[ \frac{1}{1 - |S_{22}|^2} \right] \quad (4.23)$$

$$G_{transistor,max} = 10 \log_{10} [|S_{21}|^2] \quad (4.24)$$

Therefore, the maximum unilateral transducer gain will be:

$$G_{TU,max} = G_{s,max} + G_{L,max} + G_{transistor,max} \quad (4.25)$$

The value of  $G_{TU,max}$  is then compared with the required input band gain that the user key in earlier at Step 1. If the value does not meet the requirement, changes are required (depends on user). If the user specification is within +1dB/-1dB of the value of the maximum unilateral transducer gain, it is acceptable. All of the above equations are simulated in MATLAB automatically and output value will be generated.

#### **Step 5**

**Determine the input and output return loss.**

Input return loss is the measure of how close the actual input impedance of the network is to the nominal system impedance value. Same concept goes to the output return loss. In other words, we can evaluate how well a device is matched by looking at the return loss. When the return loss is higher, it is said to have better matching. High return loss will result in low insertion loss.

$$\text{Input Return Loss} = S_{11}^* \quad (4.26)$$

$$\text{Output Return Loss} = S_{22}^* \quad (4.27)$$

### Step 6

#### **Determine the Noise Figure.**

Noise Figure will be an important aspect when we design a microwave transistor amplifier besides stability and gain. The formula of determining the Noise Figure will be as below:

$$F = F_{min} + 4 \frac{R_n}{Z_o} \frac{|\Gamma_s - \Gamma_{opt}|^2}{|1 + \Gamma_{opt}|^2 (1 - |\Gamma_s|^2)} \quad (4.28)$$

**<Noise Parameter>**

**V<sub>DS</sub> = 3 V, I<sub>D</sub> = 10 mA**

| Freq.<br>(GHz) | NF <sub>MIN.</sub><br>(dB) | G <sub>a</sub><br>(dB) | Γ <sub>opt</sub> |            | R <sub>n</sub> /50 |
|----------------|----------------------------|------------------------|------------------|------------|--------------------|
|                |                            |                        | MAG.             | ANG.(deg.) |                    |
| 2.0            | 0.65                       | 16.0                   | 0.75             | 37         | 0.52               |
| 4.0            | 0.80                       | 12.2                   | 0.66             | 78         | 0.42               |
| 6.0            | 1.25                       | 10.3                   | 0.56             | 124        | 0.33               |
| 8.0            | 1.75                       | 8.5                    | 0.49             | 166        | 0.20               |
| 10.0           | 2.10                       | 7.6                    | 0.47             | -151       | 0.28               |
| 12.0           | 2.65                       | 6.5                    | 0.45             | -112       | 0.49               |
| 14.0           | 3.20                       | 5.5                    | 0.46             | -64        | 0.56               |

FIGURE 10. Noise Parameter

FIGURE 10 above shows the noise parameter of the particular transistor.

The equation of Noise Figure, F will be include in the MATLAB and the value will be automatically calculated. Interpolation method is needed if the frequency is lie between the two frequencies found in the table.

### Step 7

#### **Determine the source and load impedance.**

After we get the value of Γ<sub>L</sub> and Γ<sub>S</sub> from Step 3, we can manipulate the equation of finding Γ<sub>L</sub> and Γ<sub>S</sub> in order to determine the source and load impedance. The characteristic impedance, Z<sub>o</sub> in this case is set to 50Ω. The formula for generating the source and load impedance will be as below:

**Source Impedance, Z<sub>s</sub> = R<sub>s</sub> + jX<sub>s</sub>**

$$Z_s = \frac{Z_o(1 - \Gamma_s)}{\Gamma_s - 1} \quad (4.29)$$

**Load Impedance,  $Z_L = R_L + jX_L$**

$$Z_L = \frac{Z_o(1 - \Gamma_L)}{\Gamma_L - 1} \quad (4.30)$$

The value of the  $R_L$  will be needed in Step 8.

### **Step 8**

**Determine the input and output impedance matching network.**

Impedance matching network is a very important step in designing a microwave amplifier as it can ensure the maximum power is being delivered from the source to the load by matching the source and load to the transmission line. Besides, the device's sensitivity will increase when there is more signal power is being transferred to the load with a properly matched transmission line. There are several methods that we can use for impedance matching such as lumped-element matching and single-stub matching and quarter-wave transformer. Since we are focus on narrowband amplifier design, we will be using lumped-element matching for the moment.

Lumped Element Matching Network for  $R_L > Z_o$

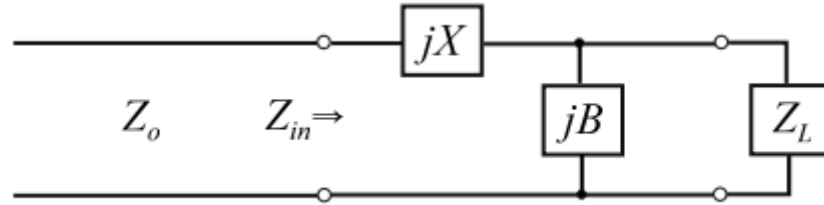


FIGURE 11. Lumped Element Matching Network for  $R_L > Z_o$

Susceptance  $jB$  and reactance  $jX$  can be any combination of inductors ( $X > 0$ ,  $B < 0$ ) or capacitors ( $X < 0$ ,  $B > 0$ ). The input impedance  $Z_{in}$  is said to match to  $Z_o$  if it is a matched network.

$$Z_{in} = Z_o = jX + \left(jB + \frac{1}{Z_L}\right)^{-1} = jX + \frac{1}{\left(jB + \frac{1}{R_L + jX_L}\right)} \quad (4.31)$$

$$Z_o = jX + \frac{R_L + jX_L}{jBR_L - BX_L + 1} \quad (4.32)$$

$$B = \frac{X_L \pm \sqrt{\frac{R_L}{Z_o} \sqrt{R_L^2 + X_L^2} - Z_o R_L}}{R_L^2 + X_L^2} \quad (4.33)$$

$$X = \frac{BZ_o R_L - X_L}{1 - BX_L} \quad (4.34)$$



Since there are two pairs of solutions for B and X, we will have two different solutions for the matching network.

Lumped Element Matching Network for  $R_L < Z_o$

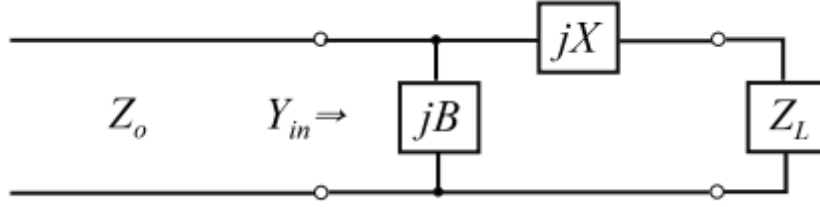


FIGURE 12. Lumped Element Matching Network for  $R_L < Z_o$

Input admittance,  $Y_{in} = \frac{1}{Z_o}$  (For a matched network)

$$B = \frac{1}{Z_o} \sqrt{\frac{(Z_o - R_L)}{R_L}} \quad (4.35)$$

$$X = \pm \sqrt{R_L(Z_o - R_L)} - X_L \quad (4.36)$$

The values of the capacitors and inductors can be get from the formula below:

$$jB_1 = j\omega C_1 \quad (4.37)$$

$$jX_1 = j\omega L_1 \quad (4.38)$$

$$jB_2 = j\omega C_2 \quad (4.39)$$

$$jX_2 = j\omega L_2 \quad (4.40)$$

All of the equations will be keying in into the MATLAB and the values of C and L will be automatically generated.

## 4.2 GUI Development in MATLAB

After launching the MATLAB R2013b, in the command window, the file name 'Untitled1' is typed to open the GUI [11].

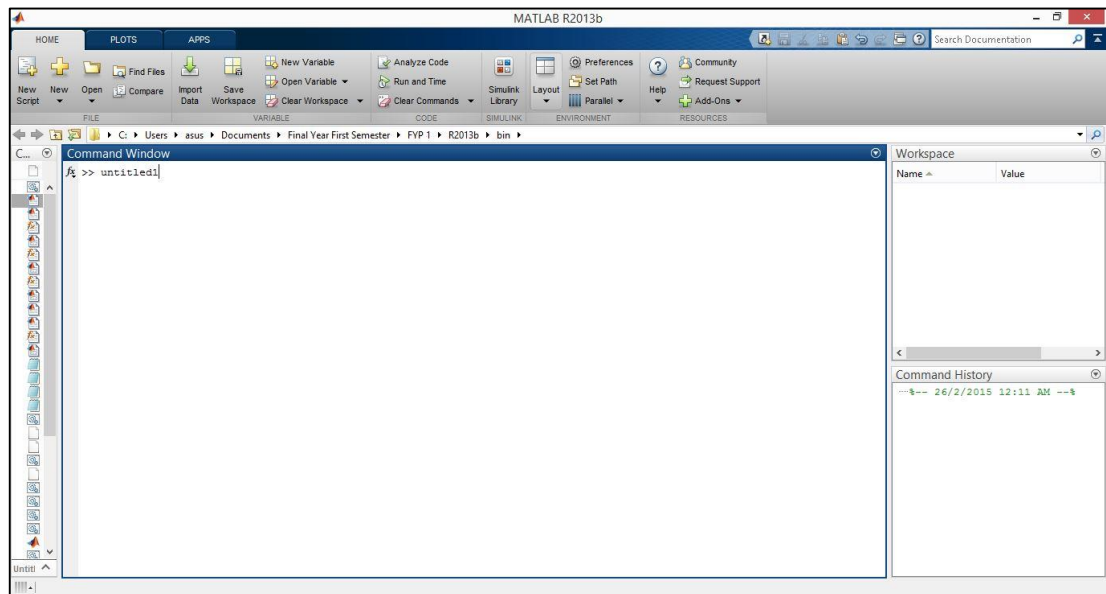


FIGURE 13. Open GUI from Command Window in MATLAB

The GUI window is popping out.

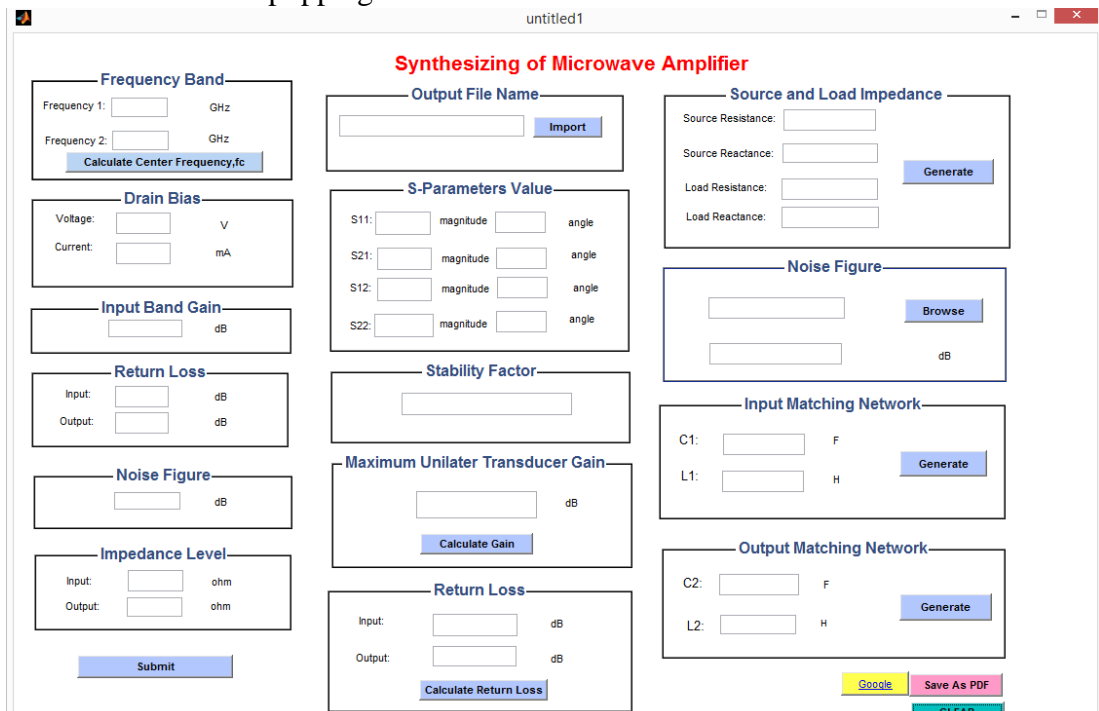


FIGURE 14. GUI

After the panels have been created, user will key in the required values of different parameters. Besides, user required to 'Enter' each time they enter a value. A Value Entered Error dialogue box will appear on the window if there the column is left blank. To close the dialogue box, user have to click button 'Ok'.

The screenshot displays a software window titled "untitled1" with the main heading "Synthesizing of Microwave Amplifier". The interface is organized into several panels for parameter input:

- Frequency Band:** Includes input fields for "Frequency 1" (16 GHz) and "Frequency 2" (17 GHz), with a "Calculate Center Frequency,fc" button.
- Drain Bias:** Includes input fields for "Voltage" (1.5 V) and "Current" (10 mA).
- Input Band Gain:** Includes an input field for "12 dB".
- Return Loss:** Includes input fields for "Input" (5 dB) and "Output" (10 dB).
- Noise Figure:** Includes an input field for "3 dB".
- Impedance Level:** Includes input fields for "Input" (50 ohm) and "Output" (ohm), with a "Submit" button.
- Output File Name:** Includes an input field and an "Import" button.
- S-Parameters Value:** Includes input fields for S11, S21, S12, and S22. An error dialog box is overlaid on this panel, stating "Value Entered Error" and "Cannot leave the column blank", with an "OK" button.
- Source and Load Impedance:** Includes input fields for "Source Resistance", "Source Reactance", "Load Resistance", and "Load Reactance", with a "Generate" button.
- Stability Factor:** Includes an input field.
- Maximum Unilateral Transducer Gain:** Includes an input field and a "Calculate Gain" button.
- Return Loss (bottom):** Includes input fields for "Input" and "Output" (both dB), with a "Calculate Return Loss" button.
- Noise Figure (bottom):** Includes an input field and a "Browse" button.
- Input Matching Network:** Includes input fields for "C1" (F) and "L1" (H), with a "Generate" button.
- Output Matching Network:** Includes input fields for "C2" (F) and "L2" (H), with a "Generate" button.

At the bottom right, there are buttons for "Google", "Save As PDF", and "CLEAR".

FIGURE 15. Dialogue Box (Cannot Leave Blank)

If the user accidentally entered a non-numeric value and press ‘Enter’, a dialogue box will appear on the window.

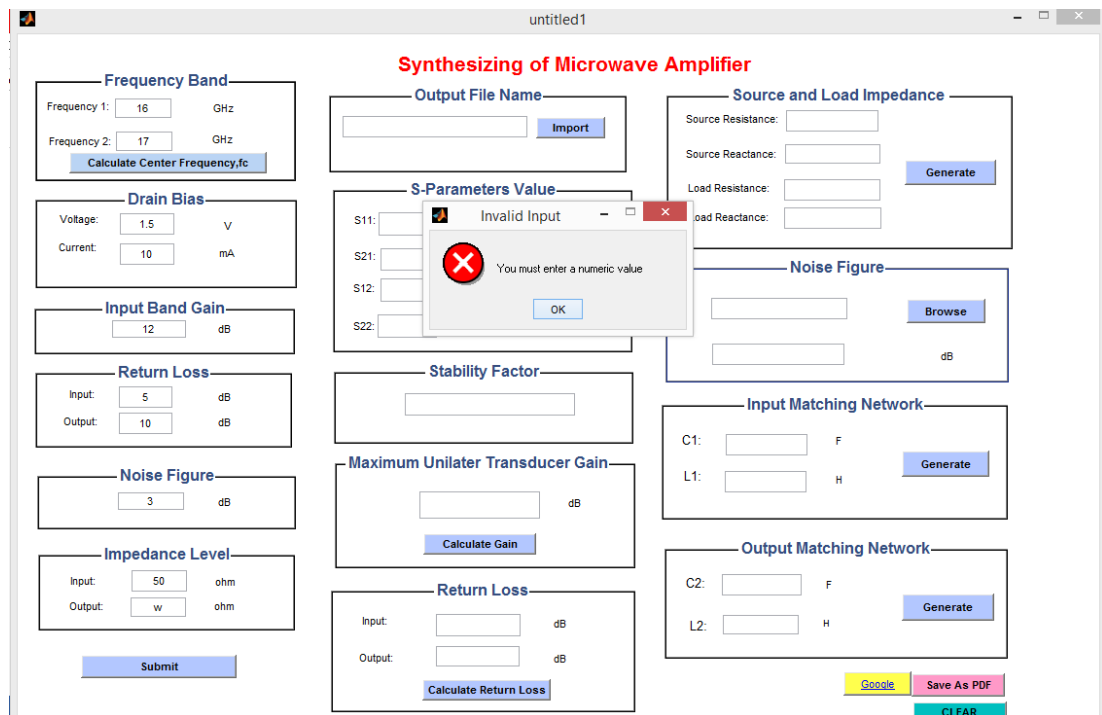


FIGURE 16. Dialogue Box (Enter Numeric Value)

After user enters all of the values, ‘Submit’ button is pressed. A dialogue box will appear on the window to ask for confirmation before submission. If ‘Yes’ is pressed, the values will be stored. Else it will return to the GUI window and user is allowed to make changes.

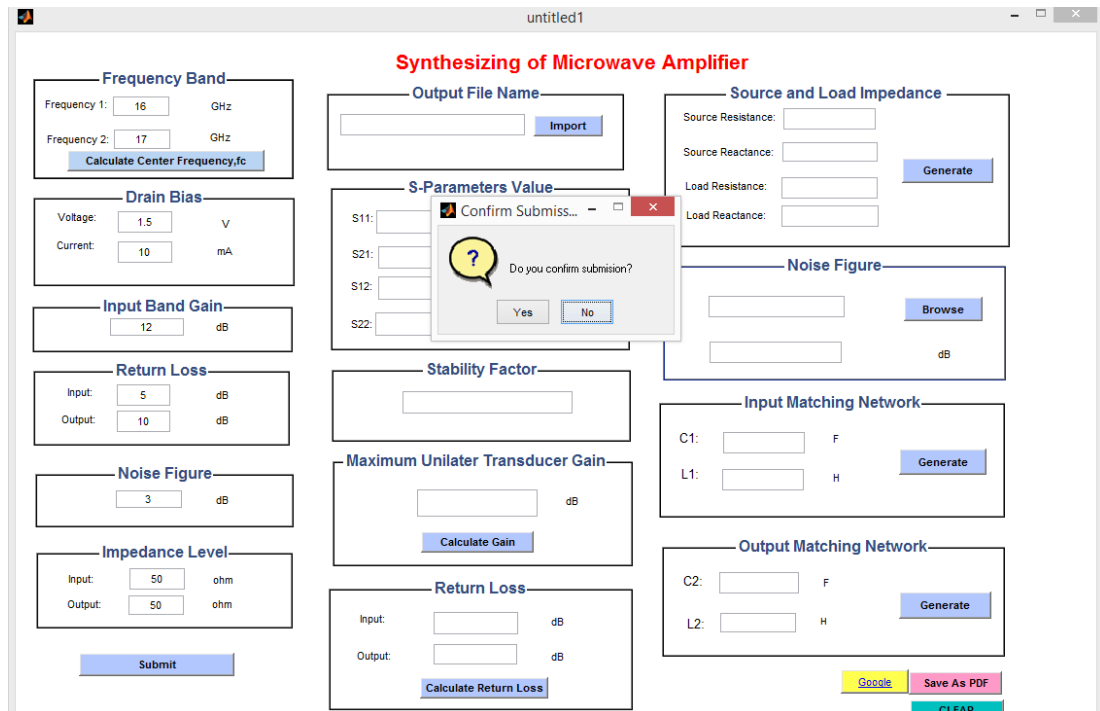


FIGURE 17. Submission Confirmation Dialogue Box

From the Output File Name Panel, user is required to import the S-Parameters of transistor. The user can choose to show data files only in touchstone file format (\*.s2p).

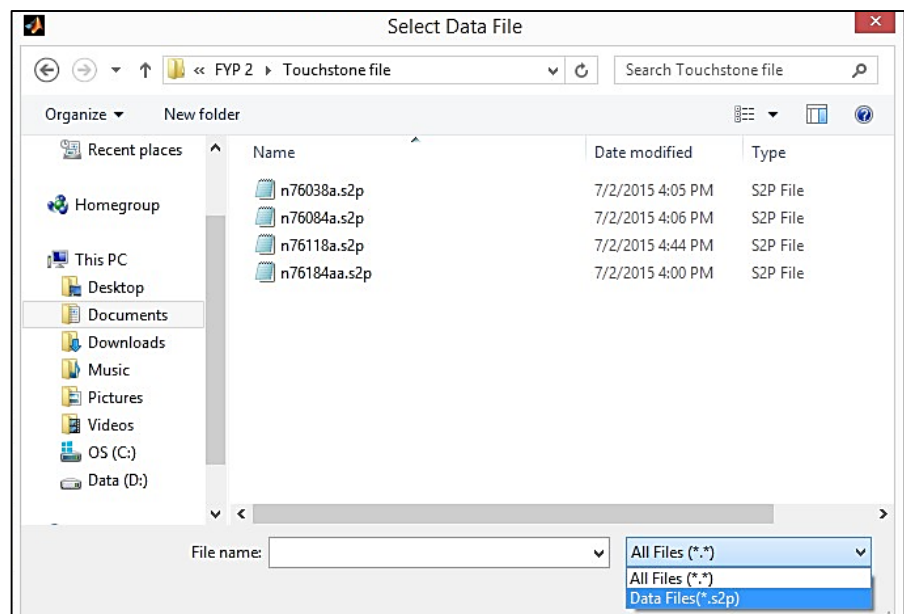


FIGURE 18. Select Data File Window

The name of the touchstone file will be shown in the column.

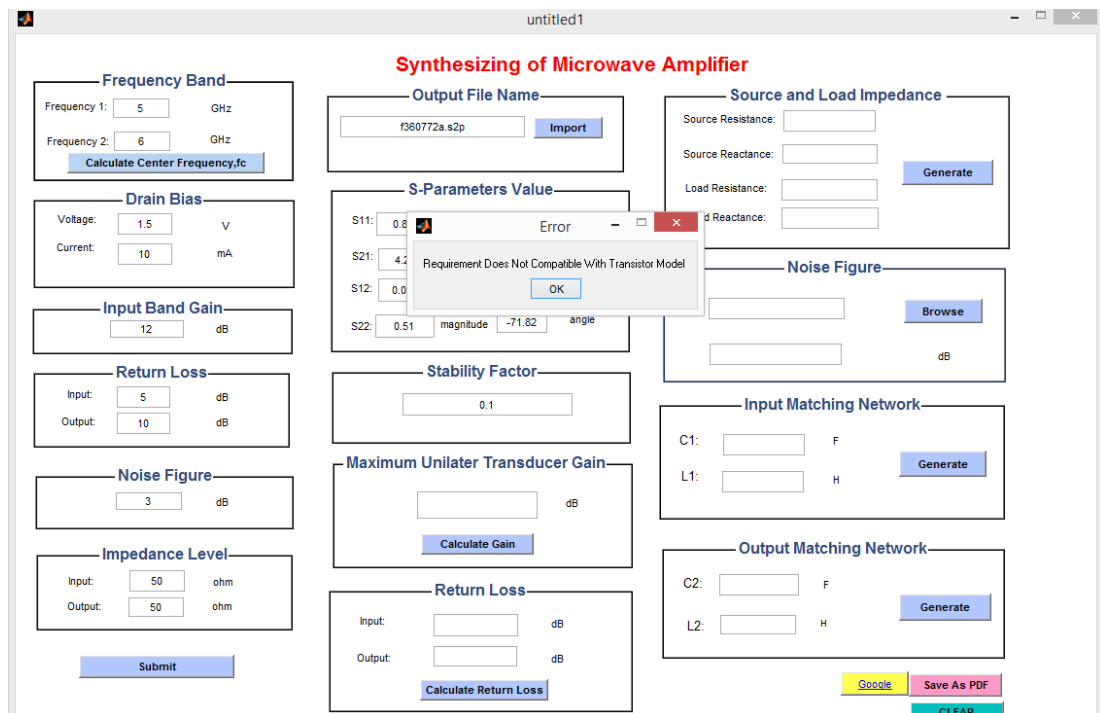


FIGURE 19. Error Dialogue Box (Incompatible of Transistor Model)

The S-parameters will be extracted automatically from the touchstone file that has been selected and shown in the S-Parameters Value Panel. In addition, the Stability Factor will be generated and Error dialogue box will be shown if the stability factor generated does not meet user's requirement. User can re-select the touchstone file of another transistor or manipulating the user's requirement. However, if the stability factor meets the user's requirement, a Success dialogue box will be shown indicates Correct Transistor Model Selected.

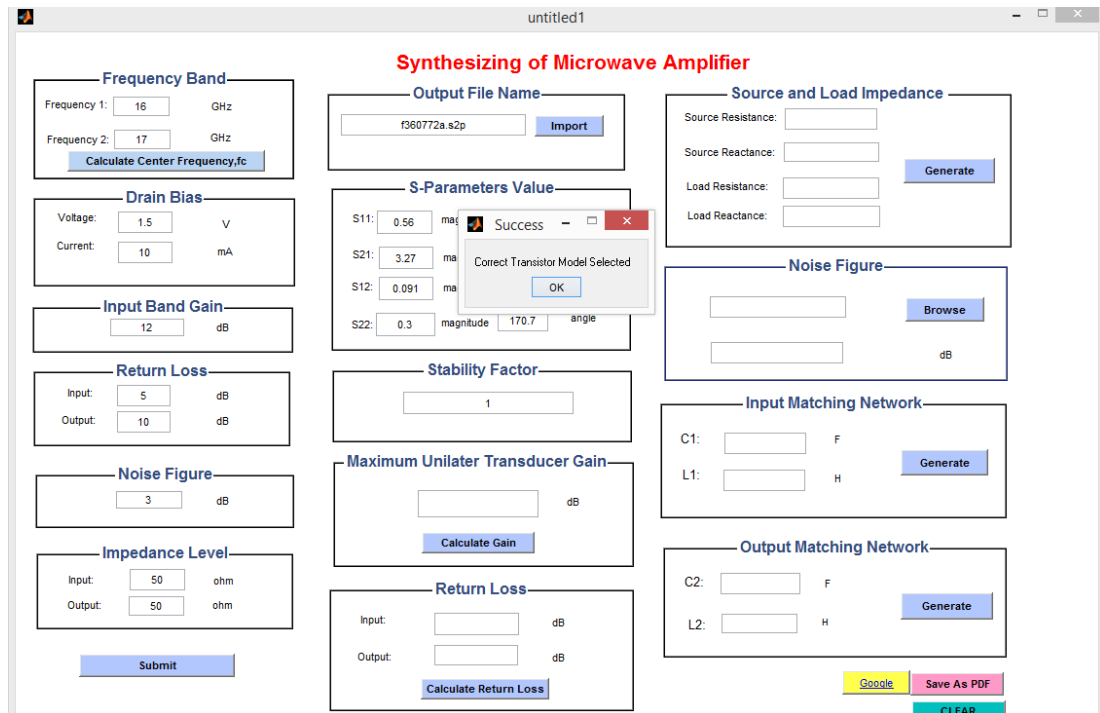


FIGURE 20. Success Dialogue Box (Compatible Transistor Model)

To get the value of the maximum unilateral transducer gain, the button ‘Generate Gain’ is pressed. If the maximum unilateral transducer gain is within +1dB/-1dB of the input band gain, a Success dialogue box indicates Input Band Gain matched will be displayed. If it is not matched, user can have the option either to re-select the transistor model or make changes to the user’s requirement.

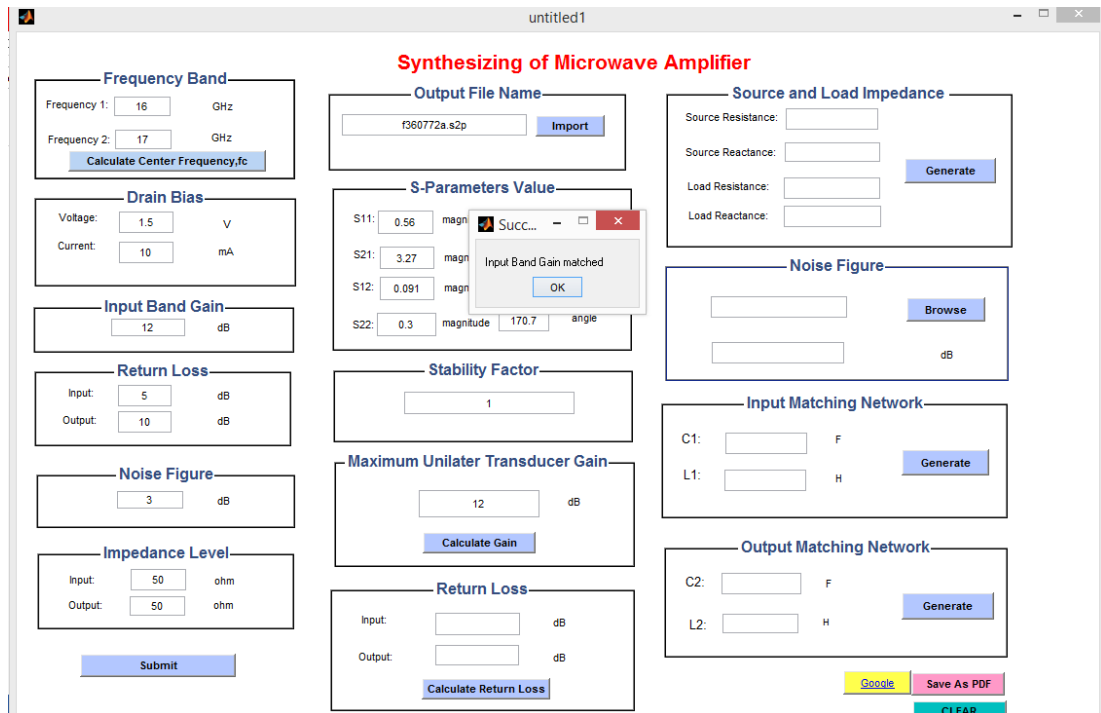


FIGURE 21. Success Dialogue Box (Input Band Gain Matched)

The input and output return loss can be calculated by pressing the Calculate Return Loss button. A warning dialogue box will appear on the screen to prompt the user to compare the generated and the user's requirement input and output band gain. In this case, it depends on the user how much they can tolerate with the input and output return loss of the specific design.

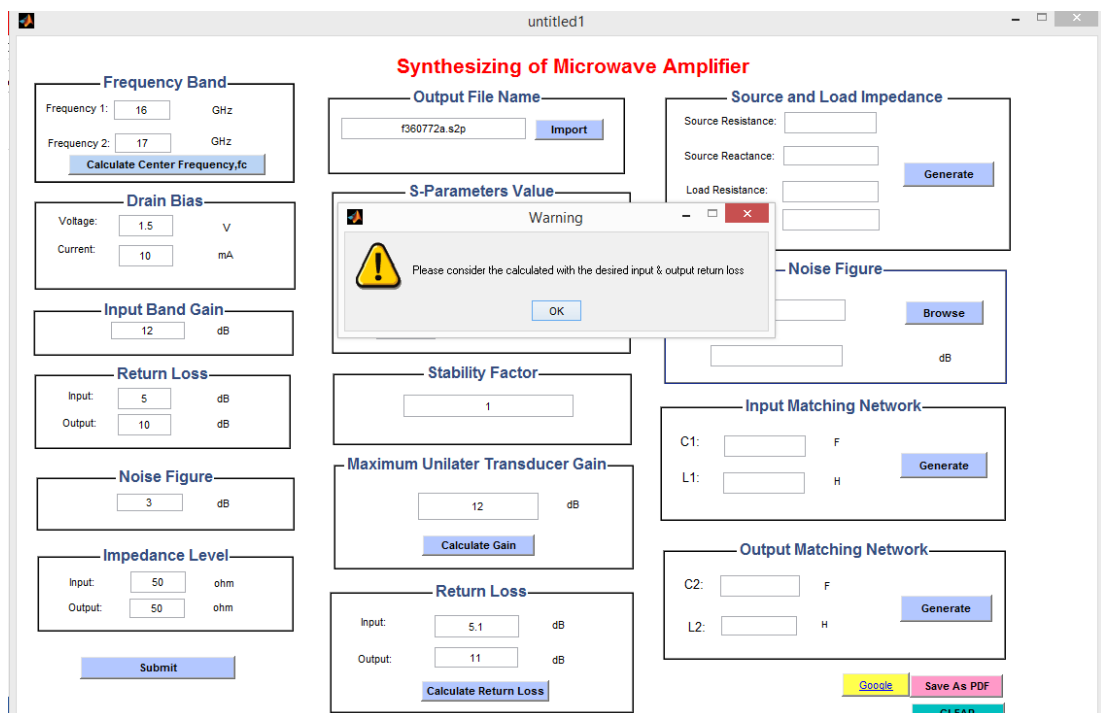


FIGURE 22. Warning Dialogue Box (Input and Output Return Loss)



The source and load impedance will be generated by pressing the Generate button on the source and load impedance panel. After that, user have to input the noise figure file of the same transistor model that has been selected earlier and user will be asked to consider the calculated and desired noise figure.

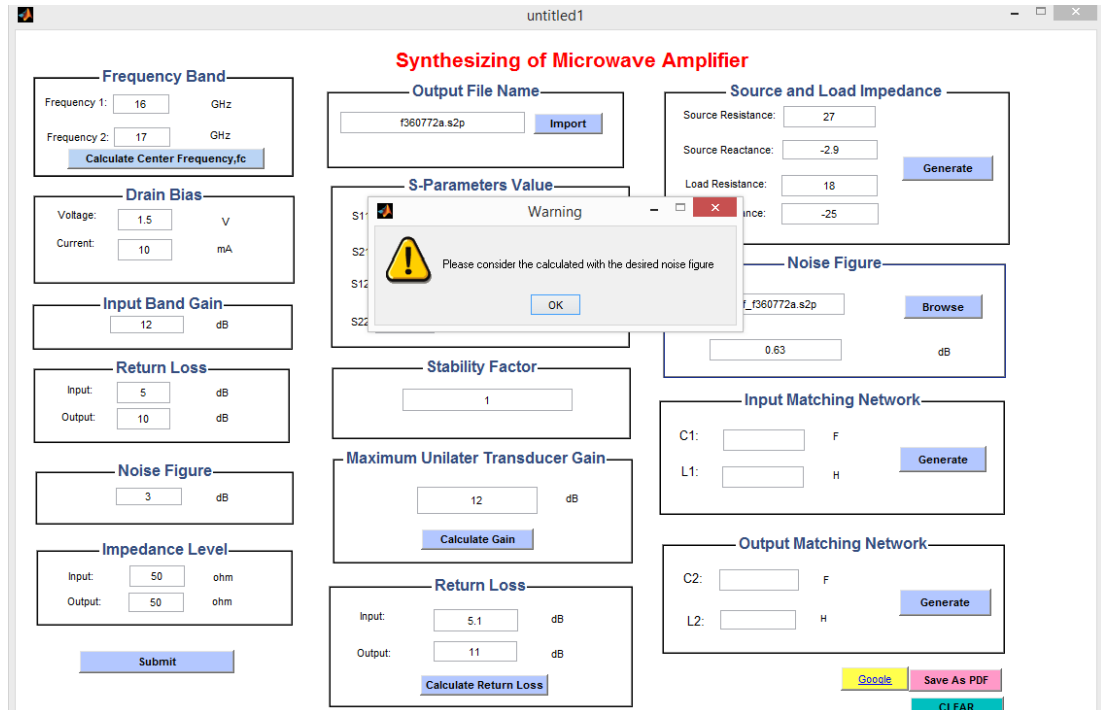


FIGURE 23. Warning Dialogue Box (Noise Figure)

The input and matching network can be get by pressing the Generate button on both panel.

**Synthesizing of Microwave Amplifier**

**Frequency Band**  
 Frequency 1: 16 GHz  
 Frequency 2: 17 GHz  
 Calculate Center Frequency,fc

**Drain Bias**  
 Voltage: 1.5 V  
 Current: 10 mA

**Input Band Gain**  
 12 dB

**Return Loss**  
 Input: 5 dB  
 Output: 10 dB

**Noise Figure**  
 3 dB

**Impedance Level**  
 Input: 50 ohm  
 Output: 50 ohm

**Submit**

**Output File Name**  
 f360772a.s2p Import

**S-Parameters Value**  
 S11: 0.56 magnitude 122.6 angle  
 S21: 3.27 magnitude -43.5 angle  
 S12: 0.091 magnitude -51.02 angle  
 S22: 0.3 magnitude 170.7 angle

**Stability Factor**  
 1

**Maximum Unilater Transducer Gain**  
 12 dB  
 Calculate Gain

**Return Loss**  
 Input: 5.1 dB  
 Output: 11 dB  
 Calculate Return Loss

**Source and Load Impedance**  
 Source Resistance: 27  
 Source Reactance: -2.9  
 Load Resistance: 18  
 Load Reactance: -25  
 Generate

**Noise Figure**  
 nf\_f360772a.s2p Browse  
 0.63 dB

**Input Matching Network**  
 C1: 0.000258 F  
 L1: 0.469 H  
 Generate

**Output Matching Network**  
 C2: 0.000199 F  
 L2: 0.361 H  
 Generate

**Google Save As PDF CLEAR**

FIGURE 24. GUI with Values Entered

If the user wishes to re-enter a different set of parameters, CLEAR button is used to reset all of the data. Besides, user also can have the option to save the parameters generated into a PDF file for future reference. The user can search the relevant information regarding the microwave amplifier by pressing GOOGLE button and it will be directed to Google homepage if there is internet connection.

## **CHAPTER 5**

### **CONCLUSION AND RECOMMENDATIONS**

#### **5.1 Conclusion**

The typical technique for microwave transistor amplifier design involves several steps from transistor selection to network matching. Therefore, time effectiveness can be greatly improved through the implementation of GUI for synthesis of microwave transistor amplifier. As a result, implementation of GUI is a potential alternative for synthesis of microwave transistor amplifier which is time-consuming. Besides, the accuracy of the synthesis of microwave transistor amplifier can be guaranteed as the calculations of the polynomial equations are done using the automated software. The main objective of the research work is achieved as the implementation of GUI as an alternative for microwave amplifier design can help to speed up the design effort of a microwave transistor amplifier. As the research work involves the use of MATLAB software and knowledge from Electromagnetic Theory, it is said to be feasible and achievable within the sufficient time frame. The work done is in parallel with the Gantt chart. In this project, the GUI is developed and it starts by prompting the user for several requirements and the required parameters such as stability factor, input and output loss, maximum unilateral transducer gain, source and load impedance, noise figure as well as the input and output impedance matching values will be auto-generated in the GUI. The data generated in the GUI can be saved in a PDF file for future reference. Besides, the user can clear all of the data in the columns by pressing 'CLEAR' button and re-enter the required specification without the need of re-run the MATLAB program. Most importantly, the developed GUI is cost effective as user does not need to purchase another software in user to do the synthesizing of microwave transistor amplifier. The GUI developed using MATLAB software is user-friendly and user does not need to have good programming skills in order to

use it. In short, the research work can be contributed to software developer and also will assist microwave circuit designers.

## **5.2 Recommendation**

Graphical User Interface (GUI) is an effective tool that can reduce the time needed to design a microwave amplifier. In the future, the function of the GUI can be enhanced by adding extra features to it. Besides synthesizing microwave transistor amplifier, it is hope that the GUI is able to synthesize other type of microwave amplifier for example microwave power amplifier. Besides, the synthesizing of the impedance matching network of the microwave amplifier can be improved by constructing the circuit of the matched network in MATLAB. In the future, the design can also be improved by auto-finding the suitable transistor from touchstone file based on user specification. The design specification can be validated using software such as ADS. In addition, the GUI development of the synthesis of microwave transistor amplifier can be further developed in LabVIEW which utilized graphical programming language.

## REFERENCES

- [1] Whatls.com (2015). amplifier. [Online]. Available:  
<http://whatis.techtarget.com/definition/amplifier>
- [2] wiseGeek (2014). What Is a Microwave Amplifier?. [Online]. Available:  
<http://www.wisegeek.com/what-is-a-microwave-amplifier.htm>
- [3] Amplifiers. [Online]. Available:  
[http://www.iitg.ernet.in/engfac/krs/public\\_html/lectures/ee441/lecture\\_slides\\_5.pdf](http://www.iitg.ernet.in/engfac/krs/public_html/lectures/ee441/lecture_slides_5.pdf)
- [4] D. Woods, "Reappraisal of the unconditional stability criteria for active 2-port networks in terms of S parameters," *IEEE Trans. Circuits Syst.*, vol. 23, pp. 73–81, Feb. 1976.
- [5] M. Ohtomo, "Proviso on the unconditional stability criteria for linear Two port," *IEEE Trans. Microwave Theory Tech.*, vol. 43, pp. 1197–1200, May 1995.
- [6] "Stability analysis and numerical simulation of multi-device amplifiers," *IEEE Trans. Microwave Theory Tech.*, vol. 41, pp. 983–991, June/July 1993.
- [7] G. Scotti, P. Tommasino, and A. Trifiletti, "A synthesis oriented approach to design stable circuits," *Microwave Opt. Technol. Lett.*, pp. 351–353, Dec. 1999.
- [8] A. Platzker, W. Struble, and K. Hetzler, "Instabilities diagnosis and the role of K in microwave circuits," in *IEEE MTT-S Int. Symp. Dig.*, 1993, pp. 1185–1188.
- [9] D. J. Mellor and L. G. Pierson, "Calculator-Based Synthesis Routine Speeds Microwave Amplifier Design," in *Microwave Symposium Digest, 1977 IEEE MTT-S International*, 1977, pp. 130-133.
- [10] M. N. A. Halim, Z. Awang, and N. H. Baba, "Computer-aided synthesis of matching networks for multi-stage broadband microwave amplifiers," in *Applied Electromagnetics, 2005. APACE 2005. Asia-Pacific Conference on*, 2005, p. 5 pp.
- [11] S.J.Chapmen, *MATLAB Programming for Engineers*, 2<sup>nd</sup> ed. Canada: Brooks/Cole, 2002.